Decision Support for Offshore Wind Turbine Installation

Novel approach to weather window estimation based on statistical analysis of installation equipment response

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Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

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Novel approach to weather window estimation based on statistical analysis of installation equipment response

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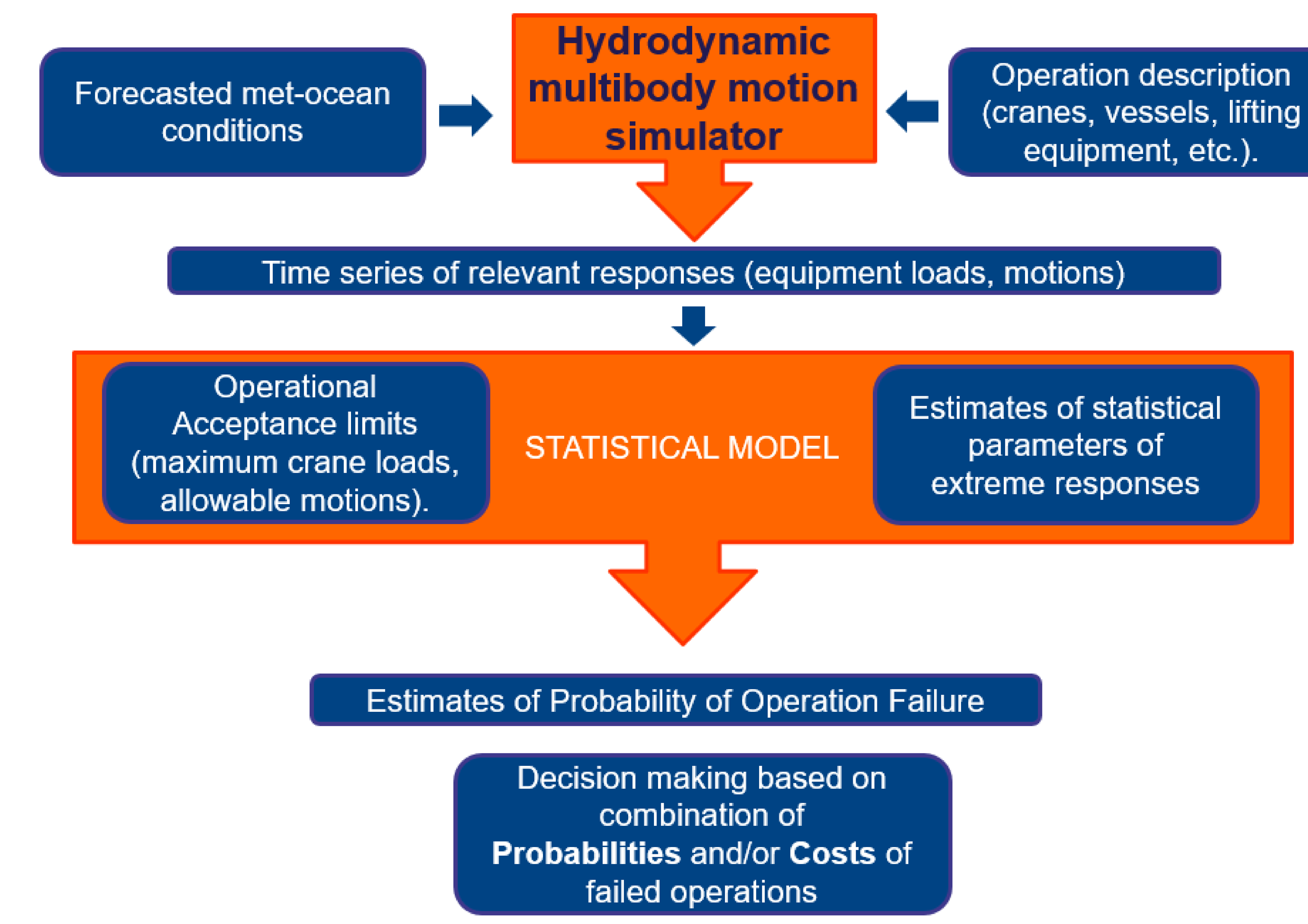
Abstract

Costs of operation & maintenance, assembly, transport and installation of offshore wind turbines contribute significantly to the total cost of offshore wind farm. These operations are mostly carried out by specific ships that must be hired for the operational phase and for duration of installation process, respectively. Duration, and therefore ship hiring costs is, among others, driven by waiting time for weather windows for weather-sensitive operations.

Today, state of the art decision making criteria for weather-sensitive operations are restrictions to the significant wave height and the average wind velocity at reference height. However, actual limitations are physical, related to response of equipment used e.g. crane wire tension, rotor assembly motions while lifting, etc. Transition from weather condition limits to limits on physical equipment response in decision making would improve weather window predictions, potentially reducing cost of offshore wind energy. This poster presents a novel approach to weather window estimation using ensemble weather forecasts and statistical analysis of simulated installation equipment response. An important aspect of any novel methodology is evaluating how well it performs compared to the standard methods given the same input. Both – proof of concept and evaluation are done and presented in a form of synthetic case study – an offshore wind turbine rotor lift operation at the FINO3 met-mast location. Performance of both methods is measured in terms of number and length of predicted weather windows.

Graphical representation of the model

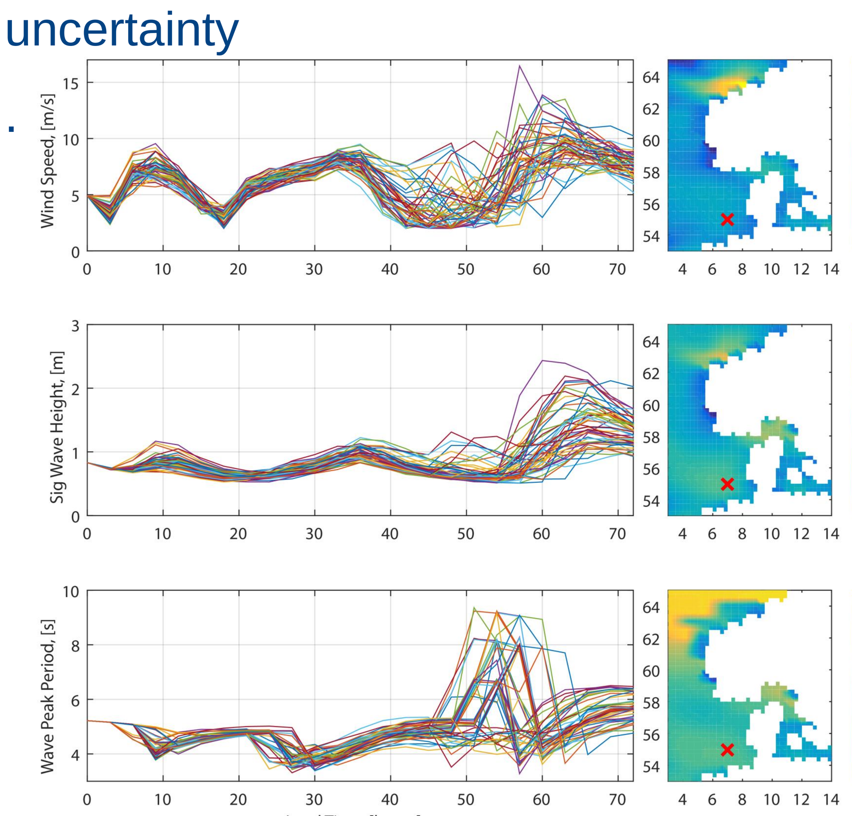


Methods

Weather Input to SIMO

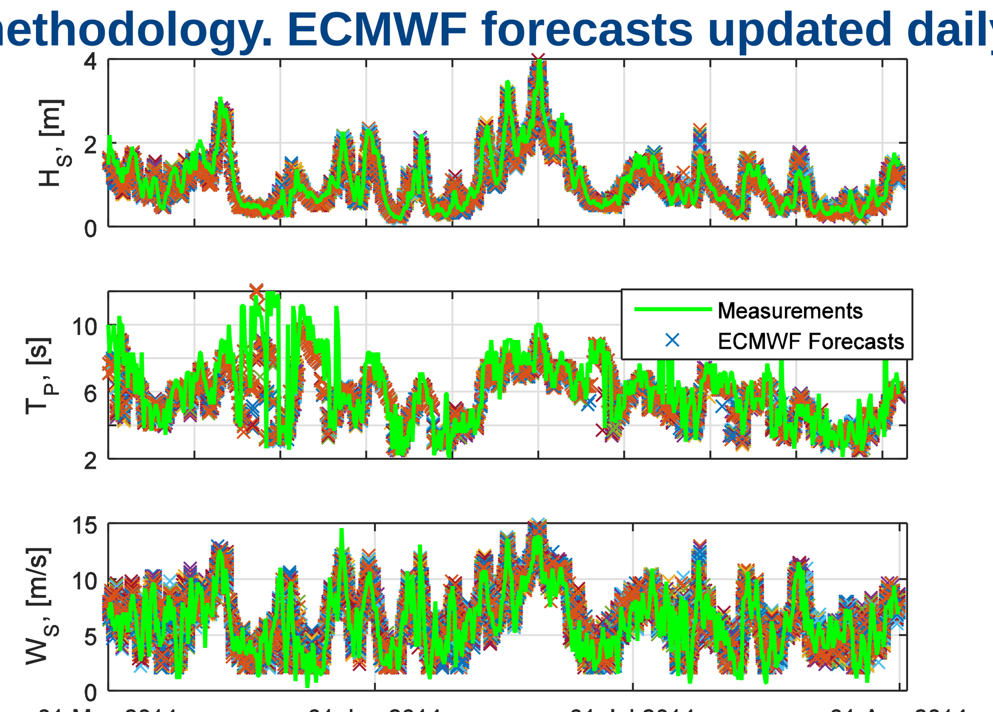
Short term study – proof of concept. ECMWF weather forecasts, 3 days lead time:

- Multiple weather parameters (wind speed and direction, wind-sea and swell parameters and directions).
- 51 forecast ensembles to ensure low statistical uncertainty
- .



Weather forecast for FINO3 site

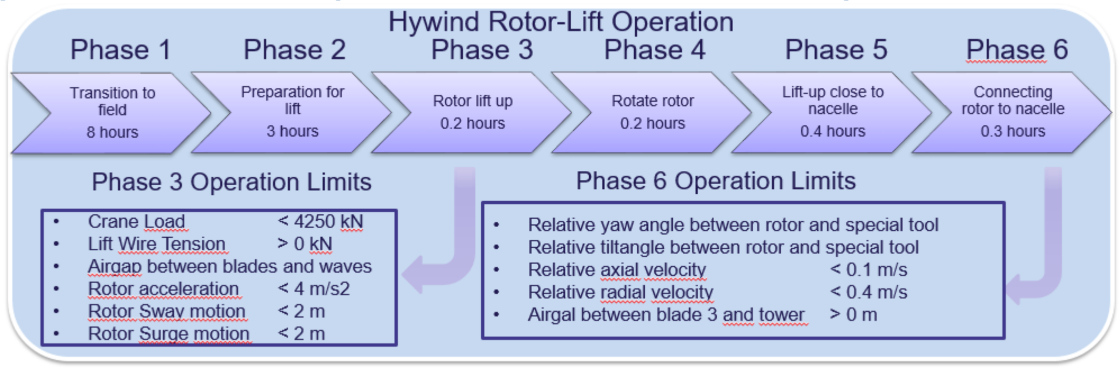
Long term study – verification of proposed methodology. ECMWF forecasts updated daily

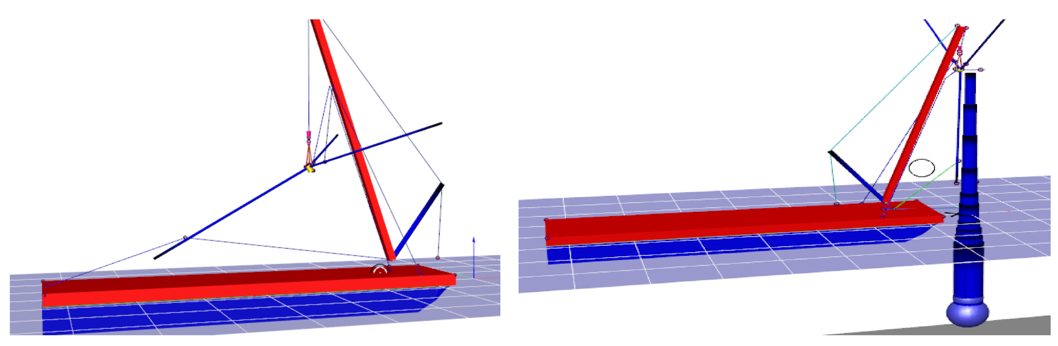


- Forecasts (scatter) and measurements (green line) for summer of 2014.

Proposed methodology. Proof of concept and verification

SIMO software is used to simulate the installation sequence using systems of barges, cranes, control wires/tugs and wind turbine components. The installation process is split into different phases. Each phase has multiple failure criteria, example:



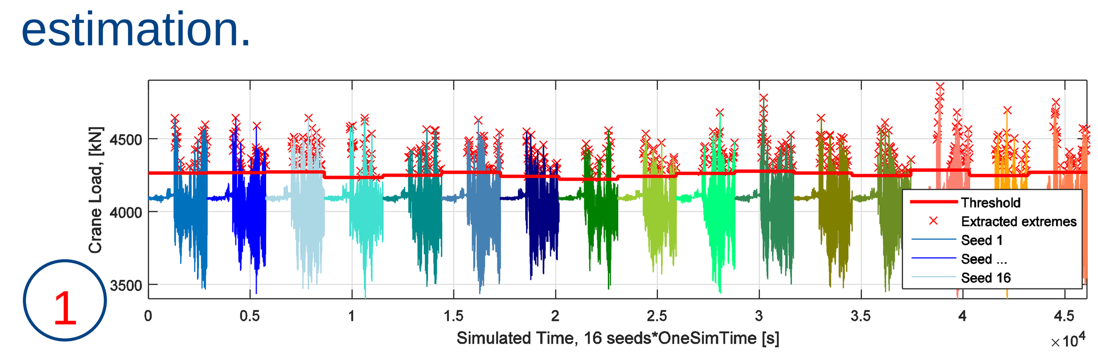


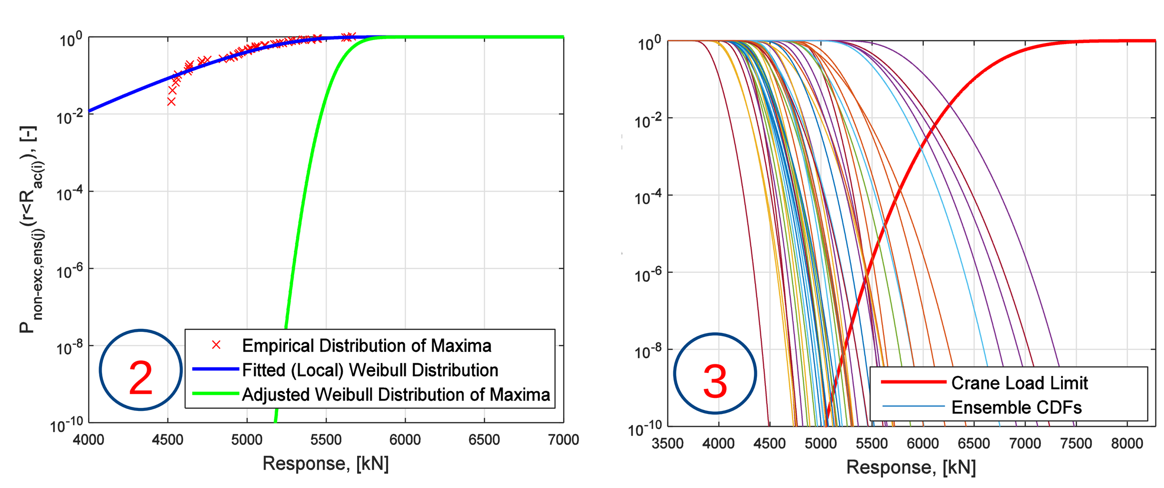
Rotor lift-up from barge and bolting to the nacelle.

Weather forecasts are passed through SIMO and response time series are analysed statistically in order to obtain Probabilities of Failed operations:

1. Peak Over Threshold method is applied to extract extreme values of relevant responses.

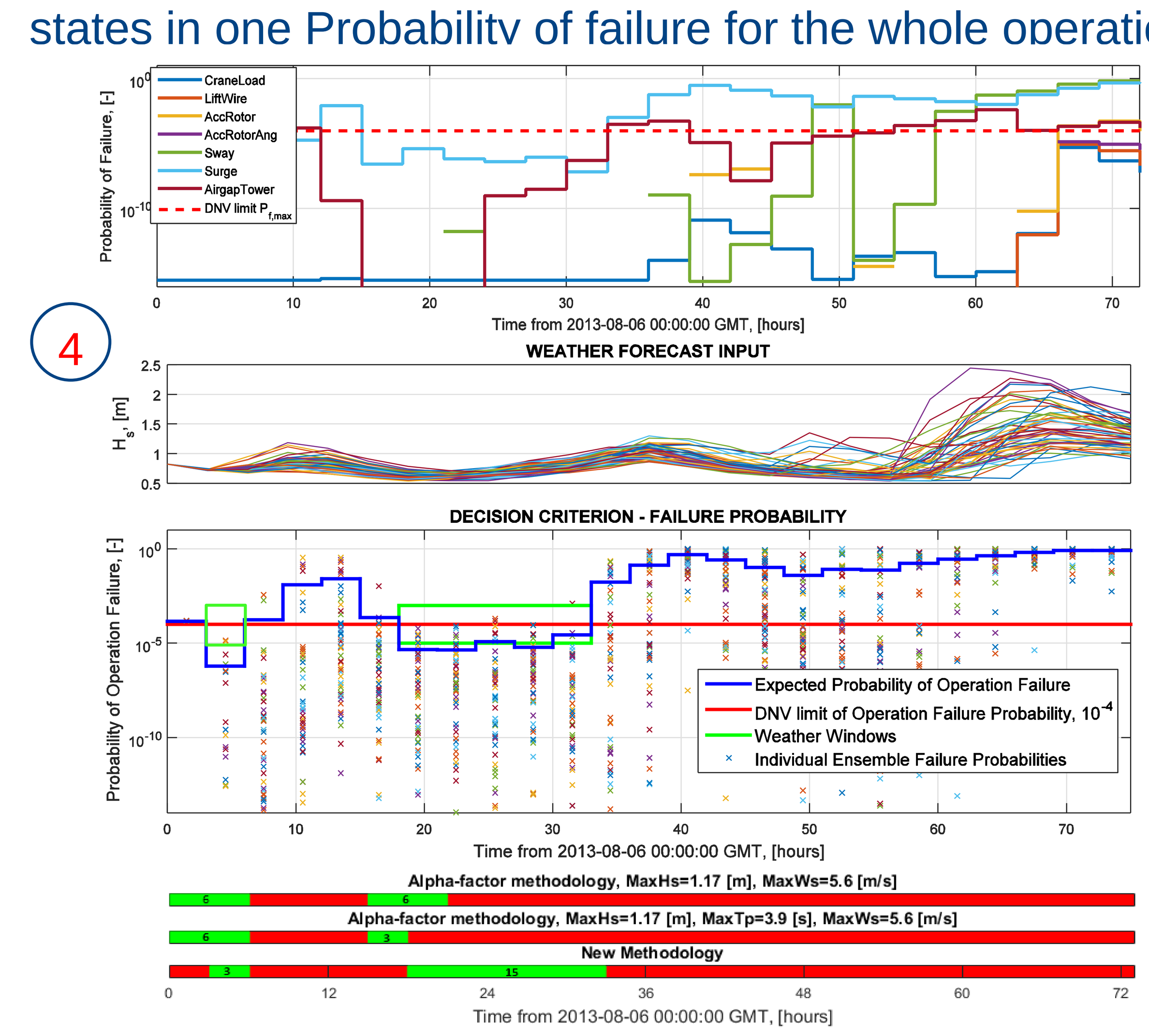
2. Weibull or Normal distribution is fitted to the extremes using Maximum Likelihood parameter estimation.





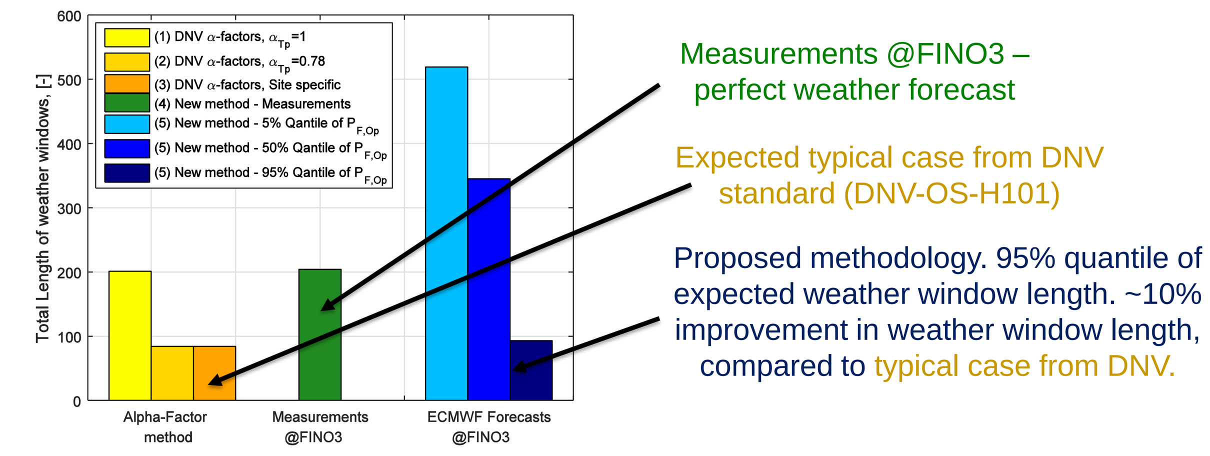
3. Steps 1-2 are repeated for 51 forecast ensembles individually (example lead time 36 hours).

4. The Probability of Failure for one acceptance limit is estimated using the 51 ensembles. Combining all the limits states in one Probability of failure for the whole operation.



Results of long term verification study

- The proposed methodology is performing better, with ~10% improvement in terms of total length of predicted weather windows for the test period in the example than the standard alpha-factor method.
- Weather forecast uncertainty plays a central role in the number and duration of estimated weather windows. More and longer weather windows were obtained when using a "perfect weather forecast" case compared to 95% quantile of "uncertain weather forecast" case.



Acknowledgments

The research is funded by The Research Council of Norway, project No. 225231/070 - Decision support for offshore wind turbine installation. The authors also acknowledge Christian Michelsen Research, Meteorologisk Institut (Norway), MARINTEK, Uni Research, University of Bergen (UiB) and STATOIL for their valuable inputs and support.

Conclusions

It can be concluded that the procedure for estimation of Probability of Failed Operations produces consistent results and could be used to assist in decision making for Offshore Wind Turbine installation. The proposed methodology is performing better - with ~10% improvement in terms of total length of predicted weather windows. With weather increasing forecast uncertainty the length and total number of weather windows decreases. Using better, less uncertain, weather forecasts. would be very beneficial for performance of proposed method.

T. Gintautas, J. D. Sørensen, S. R. Vatne, Towards a Risk-based Decision Support for Offshore Wind Turbine Installation and Operation and Maintenance, Energy Procedia, Volume 94, September 2016, Pages 207-217, ISSN 1876-6102

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